



# Epidemiology of Diarrhea for Chinese Dairy Calves: A Systematic Review and Meta-analysis

J.C. Qu<sup>1,2,3</sup>, C. Meng<sup>1,2,3</sup>, L.Y. Li<sup>1,2,3</sup>, H. Zhu<sup>1,2,3</sup>, G.A. Yin<sup>1,2,3</sup>

10.18805/IJAR.BF-1549

## ABSTRACT

Calf diarrhea is one of the most serious diseases in the dairy industry, which has caused huge economic losses to the worldwide dairy industry, including China. We conducted a meta-analysis to systematically assess the prevalence and associated risk factors of diarrhea among dairy calves in China. The China Science and Technology Journal, China National Knowledge Infrastructure (CNKI), Wan Fang and Pub Med databases were systematically searched from the inception dates to April 30, 2022, using keywords of prevalence, diarrhea, calves, key factors, determinants, related factors, causes, etiology, prevalence, epidemiology and China. A meta-analysis was performed to calculate 95% CIs using random-effects models. 35 studies reporting the prevalence of dairy calves' diarrhea in China were selected upon our inclusion criterion. The pooled diarrhea prevalence in dairy calves in China was estimated to be 27.2% (95% CI 24.2-30.2). The results of our systematic review and meta-analysis revealed that the highest prevalence rate was found in Northeast China, followed by Northwest China and East China and the lowest two regions were Northern and central China. The main cause of diarrhea in calves is bacteria, the second is virus and the third is a parasite.

**Key words:** Calf diarrhea, China, Meta-analysis, Prevalence, Systematic review.

Calf diarrhea is one of the most serious diseases in the dairy industry. Particularly in large-scale feeding, the incidence of diarrhea is commonly at 90%-100% and the mortality can be more than 50% at the highest status. When happening diarrhea, calves mainly show diverse clinical symptoms including depression, temperature rising, loss of appetite abdominal distention and pain, acute diarrhea, faeces with stench or mixed with bloodshot, dehydration and autotoxicosis, which caused a great influence on its survival rate, growth and development. Thus, diarrhea is generally called a newborn calf killer (Sun 2003) resulting in significant economic losses for the dairy industry.

The causes of calves' diarrhea are complex and can be roughly divided into infectious and non-infectious factors, which are closely related and complement each other. Infectious factors include viral infection, such as bovine coronavirus, bovine rotavirus and bovine viral diarrhea virus, etc., bacterial infection, including *Escherichia coli*, *Salmonella* and *Shigella*, etc., parasitic infection, including *Cryptosporidium parvum*, etc (Zhi et al., 2015).

To the best of our knowledge, the national-wide seroprevalence of diarrhea in dairy calves in China remains unknown. Therefore, we conducted this systematic review and meta-analysis to explore the epidemiology dynamics and diarrhea seroprevalence in dairy calves, which provide a theoretical basis for further extensive, comprehensive investigation and effective intervention measures according to different disease areas and different pathogens.

## Search strategy

Four databases, China Science and Technology Journal, China National Knowledge Infrastructure (CNKI), Wan Fang and Pubmed, were searched for relevant literatures without

<sup>1</sup>College of Animal Science and Veterinary Medicine, Heilongjiang Bayi Agricultural University, Daqing, Heilongjiang, 163319, P.R. China.

<sup>2</sup>Heilongjiang Key Laboratory of Efficient Utilization of Feed Resources and Nutrition Manipulation in Cold Region, Heilongjiang Bayi Agricultural University, Daqing, Heilongjiang, 163319, P.R. China.

<sup>3</sup>Key Laboratory of Low-carbon Green Agriculture in Northeastern China, Ministry of Agriculture and Rural Affairs, P.R. China.

**Corresponding Authors:** G.A. Yin and H. Zhu, College of Animal Science and Veterinary Medicine, Heilongjiang Bayi Agricultural University, Daqing, Heilongjiang, 163319, P.R. China.

Email: guoanyin@foxmail.com; zhuhuan1982@sina.com

**How to cite this article:** Qu, J.C., Meng, C., Li, L.Y., Zhu, H. and Yin, G.A. (2023). Epidemiology of Diarrhea for Chinese Dairy Calves: A Systematic Review and Meta-analysis. Indian Journal of Animal Research. 57(2): 139-146. doi: 10.18805/IJAR.BF-1549.

**Submitted:** 09-06-2022 **Accepted:** 21-09-2022 **Online:** 30-09-2022

date restriction. We focused on the infectious data on diarrhea of dairy calves in China and the deadline was set for April 30, 2022. The principle keywords included "prevalence", "diarrhea", "calves", "key factors", "determinants", "related factors", "causes", "etiology", "prevalence", "epidemiology" and "China". The searching process excluded literature of investigation, literature with animals other than calves (such as pigs, bison, buffaloes, beef and yaks), literature with a sample size of less than 30, literature with epidemiological results, literature with ambiguous diagnostic methods and literature outside China.

## Eligibility criteria

**Inclusive criteria and research field:** Studies conducted only in China.

**Population:** Studies with dairy calves only.

**Published condition:** Both published and unpublished articles were included.

**Study design:** All observational study designs (*i.e.*, cross-sectional, case-control and cohort) reporting the prevalence of diarrhea in dairy calves were eligible for this review.

### Literature screening and data extraction eligibility criteria

Data were independently extracted and recorded from each selected study by the reviewers. If there were disagreements or uncertainties on the eligibility of the study between the reviewers, it would be further assessed by other reviewers. A standardized data-collection form was used to record data as follows: the first author, publication year, pathogen, sampling mode, the number of experimental dairy calves and diarrhea dairy calves, measurement method and province. In addition, we neither contacted the authors of the original study for further information, nor identified unpublished data. The data-collection form was showed in Table 1.

### Quality assessment

The quality of an eligible publication was evaluated based on criteria that Grading of Recommendations Assessment, Development and Evaluation method. The quality of publications was graded by a scoring method. In brief, when elaborating information, the score in each followed item was determined as 1 score, including target, detection method used, sampling method and subgroup classification in the study. According to this standard, one paper can be assigned into 0-4 scores. Papers with 3 and 4 scores were of high quality, with 2 scores were deemed moderate quality and those with 0 and 1 scores were validated to be low quality. Due to different detection methods in some literatures, it should be noted that there would be inconsistent scores in the same literature when investigating different pathogens. The paper with a lower score still met the criteria for inclusion in this meta-analysis, although it might not provide further analysis information.

### Data processing and analysis

Data were extracted in a Microsoft Excel format and used to calculate the pooled prevalence of diarrhea in dairy calves by meta-analysis based on numerous publications. Since more heterogeneity will be expected in the qualified study, a random effect model was used to calculate and prepare the forest plot with Stata software (version 12.0, Stata Corp, College Station, Texas). The heterogeneity was predicted and the variation was assessed by using statistical methods with  $I^2$  and Cochran Q (represented as  $\chi^2$  and p-values) statistics. Experimental statistics indicated that there existed a significant heterogeneity between studies ( $I^2=99.0\%$ ,  $p<0.001$ ). The potential sources of heterogeneity were further investigated by subgroup analysis and Meta-regression analysis. The factors that caused heterogeneity in this study were examined by individual models or multi-variable models. These factors included publication years (before 2010 vs after 2010 or later), pathogen types and

regional differences. Point prevalence and 95% confidence interval were presented in the form of a forest map, in which the size of each box represented the weight of this study and each cross line represented a 95% confidence interval. This section might be divided into subheadings. It should provide a concise and precise description of the experimental results, their interpretation as well as the experimental conclusions that can be drawn.

### Studied included

A total of 1,708 articles related to diarrhea of calves were retrieved, in which 35 articles were selected for quantitative analysis (Table 1 and Flow Chart 1), all of which are cross-sectional study designs. The quality of each article was evaluated according to the article content, calves' diarrhea prevalence, research purpose and comprehensiveness of the presented data. In the 35 papers, 29 papers were scored as high quality (3 or 4 points), 5 papers as medium quality (2 points) and the remaining one as low quality (1 point) (Flow Chart 1).

### Publication bias

The extent of bias in the publication in selected studies was used to assess and illustrate by the funnel plot and forest plot (Fig 1 and 2). This asymmetry indicated that there was a publication bias in selected qualified papers, which might have a significant impact on analysis results (Table 1).

### Pooled prevalence of dairy calves' diarrhea in China

The results indicated that the pooled prevalence of dairy calves' diarrhea in China was 27.2% (95% confidence interval: 24.2-30.2) (Fig 2). High heterogeneity was observed in the studies ( $I^2=99.0$ ,  $p<0.001$ ). Therefore, a meta-analysis model with random effects was performed to estimate the prevalence of diarrhea in Chinese dairy calves. The meta-analysis shows that the highest prevalence was 91.7% (95% confidence interval: 85.3-98.1), while the lowest was 1.7% in other reports (0.8-2.6) Zhang *et al.*, 2017).

### Prevalence of dairy calves' diarrhea in different regions of China

According to the different regional divisions of China, the subgroup analysis was carried out in five regions, central China, East China, North China, Northeast China and Northwest China. The highest diarrhea prevalence was in Northeast China (27.5%, 95% CI 0.14-0.41), followed by Northwest China (25.2%, 95% CI 0.19-0.31) and East China (21.1%, 95% CI 0.12-0.30). The lowest diarrhea prevalence was in North China (15.2%, 95% CI 0.13-0.18) and central China (11.3%, 95% CI 0.06-0.17).

### Diarrhea prevalence of dairy calves caused by different pathogens in China

Bacteria, virus and parasite could all cause dairy calves' diarrhea. According to the analysis of different factors affecting diarrhea, the highest incidence of diarrhea was caused by bacteria (39.2%, 95% CI 0.30-0.48), followed by the virus (24.9%, 95% CI 0.19-0.31) and the lowest was caused by parasite (20.8%, 95% CI 0.15-0.27).

**Table 1:** Literatures on calf diarrhea.

Author	Year	Pathology	n	r	Region	Score
Cai <i>et al.</i> (2017)	2017	<i>Cryptosporidium</i>	818	37.04%	East	2
Chang <i>et al.</i> (2021)	2021	BVDV	788	29.82%	Northern	3
Chang <i>et al.</i> (2021)	2021	BRV	788	29.44%	Northern	3
Chang <i>et al.</i> (2021)	2021	BCV	788	18.02%	Northern	3
Chen <i>et al.</i> (2020)	2020	BVDV	79	46.95%	Northern	3
Cheng (2019)	2019	<i>Cryptosporidium</i>	22	9.09%	Central	3
Cui (2019)	2019	BRV	325	15.69%	Northwest	3
Cui (2019)	2019	BCV	325	9.54%	Northwest	3
Cui <i>et al.</i> (2014)	2014	<i>Cryptosporidium</i>	213	25.35%	Northwest	2
Dai <i>et al.</i> (2018)	2018	<i>Escherichia coli</i>	55	20.00%	Northwest	3
Dai <i>et al.</i> (2018)	2018	Giardia	55	9.09%	Northwest	3
Dai <i>et al.</i> (2018)	2018	BRV	55	21.82%	Northwest	3
Dai <i>et al.</i> (2018)	2018	<i>Cryptosporidium</i>	55	40.00%	Northwest	2
Duan <i>et al.</i> (2009)	2009	BRV	274	37.23%	Northeast	3
Gao, (2008)	2008	<i>Escherichia coli</i>	36	77.78%	Northwest	3
Jia <i>et al.</i> (2019)	2019	<i>Cryptosporidium</i>	278	14.39%	Southwest	3
Jumabieke <i>et al.</i> (2021)	2021	<i>Cryptosporidium</i>	234	8.54%	southwest	2
Jumabieke <i>et al.</i> (2021)	2021	<i>Escherichia coli</i>	234	2.99%	southwest	2
Jumabieke <i>et al.</i> (2021)	2021	BRV	234	6.41%	southwest	2
Kang <i>et al.</i> (2019)	2019	<i>Cryptosporidium</i>	24	20.83%	North	3
Li <i>et al.</i> (2016)	2016	<i>Biennial taenia</i>	879	24.35%	North	3
Li <i>et al.</i> (2018)	2018	<i>Escherichia coli</i>	53	54.72%	Northwest	3
Li, (2011)	2011	<i>Escherichia coli</i>	70	40.00%	North	3
Li, (2011)	2011	<i>Salmonella</i>	70	12.86%	North	1
Li, (2016)	2016	BVDV	986	24.44%	North	4
Li, (2016)	2016	<i>Escherichia coli</i>	3360	5.71%	North	2
Li, (2016)	2016	BCV	3360	2.20%	North	3
Li, (2016)	2016	Giardia	822	1.70%	North	1
Li, (2016)	2016	BRV	3360	11.10%	North	3
Li, (2016)	2016	<i>Coccidia</i>	2307	23.88%	North	3
Li, (2016)	2016	<i>Cryptosporidium</i>	4182	6.31%	North	3
Li, (2017)	2017	<i>Enterococcus faecalis</i>	48	47.92%	Northeast	4
Liu <i>et al.</i> (1993)	1993	<i>Clostridium welchii</i> type A	71	5.63%	Northwest	4
Liu <i>et al.</i> (1993)	1993	BVDV	127	56.69%	Northwest	4
Liu <i>et al.</i> (1993)	1993	<i>Escherichia coli</i>	71	57.75%	Northwest	4
Liu <i>et al.</i> (1993)	1993	<i>Streptococcus faecalis</i>	71	45.07%	Northwest	2
Liu <i>et al.</i> (1993)	1993	BVDV	293	50.85%	Northwest	1
Liu, (2016)	2016	<i>Escherichia coli</i>	60	61.67%	North	4
Lu <i>et al.</i> (2018)	2018	BRV	172	73.84%	Northwest	4
Ma <i>et al.</i> (2006)	2006	<i>Escherichia coli</i>	203	71.92%	East	3
Ma, (2006)	2006	<i>Escherichia coli</i>	203	51.72%	East	3
Meng <i>et al.</i> (2019)	2019	BVDV	451	78.49%	Northeast	
					Northwest East	3
Qi <i>et al.</i> (2015)	2015	<i>Cryptosporidium</i>	186	24.73%	North	4
Sun, (2016)	2016	<i>Escherichia coli</i>	420	33.33%	Northeast North	3
Wang <i>et al.</i> (1992)	1992	BVDV	156	9.62%	North	1
Wang <i>et al.</i> (2016)	2016	BVDV	117	1.71%	Northwest	4
Wang <i>et al.</i> (2016)	2016	<i>Flagellates intestinalis</i>	45	17.78%	Northeast	2
Wang <i>et al.</i> (2016)	2016	<i>Escherichia coli</i>	117	8.55%	Northwest	2
Wang <i>et al.</i> (2016)	2016	BCV	117	6.84%	Northwest	4
Wang <i>et al.</i> (2016)	2016	BRV	97	37.11%	Northeast North	3

Table 1: Continue...

Table 1: Continue...

Wang <i>et al.</i> (2016)	2016	<i>Cryptosporidium</i>	52	38.46%	North	3
Wang <i>et al.</i> (2016)	2016	Shigella	117	29.06%	Northwest	4
Wang <i>et al.</i> (2019)	2019	BNV	50	42.00%	East	3
Wang <i>et al.</i> (2019)	2019	BRV	127	32.28%	Northwest	3
Wang <i>et al.</i> (2019)	2019	<i>Cryptosporidium</i>	127	25.20%	Northwest	3
Wang <i>et al.</i> (2019)	2019	<i>Escherichia coli</i>	127	11.02%	Northwest	3
Wang <i>et al.</i> (2019)	2019	Giardia	127	4.72%	Northwest	3
Wang <i>et al.</i> (2019)	2019	BRV	127	32.28%	Southwest	3
Wang <i>et al.</i> (2021)	2021	BCV	130	13.1%	Southwest	4
Wang <i>et al.</i> (2021)	2021	BRV	130	38.5%	Southwest	4
Wang <i>et al.</i> (2021)	2021	<i>Cryptosporidium</i>	130	37.7%	Southwest	4
Wang <i>et al.</i> (2021)	2021	<i>Escherichia coli</i>	130	6.2%	Southwest	4
Wang, (2017)	2017	BCV	232	4.31%	Central East	3
					North Northeast	
					Northwest	
					Southwest	
Wang, (2017)	2017	BRV	232	34.91%	Central East	3
					North Northeast	
					Northwest	
					Southwest	
Wang, (2017)	2017	BVDV	232	9.05%	Central East	3
					North Northeast	
					Northwest	
					Southwest	
Wang, (2017)	2017	<i>Escherichia coli</i>	232	40.95%	Central East	3
					North Northeast	
					Northwest	
					Southwest	
Wang, (2017)	2017	<i>Proteus mirabilis</i>	232	3.45%	Central East	2
					North Northeast	
					Northwest	
					Southwest	
Wang, (2017)	2017	<i>Cryptosporidium</i>	232	1.72%	Central East	4
					North Northeast	
					Northwest	
					Southwest	
Wei <i>et al.</i> (2013)	2013	BRV	195	42.05%	Northwest	3
Yan <i>et al.</i> (2020)	2020	<i>Escherichia coli</i>	187	4.28%	Central	4
Yan <i>et al.</i> (2020)	2020	BVDV	187	5.56%	Central	4
Yan <i>et al.</i> (2020)	2020	<i>Cryptosporidium</i>	187	25.13%	Central	4
Yao <i>et al.</i> (2019)	2019	BVDV	145	13.10%	East	3
Yao, (2014)	2014	<i>Escherichia coli</i>	50	72.00%	Northwest	3
Yu <i>et al.</i> (2003)	2003	BVDV	3070	25.96%	East	1
Zhang (2019)	2019	<i>Cryptosporidium</i>	232	38.36%	Northwest	4
Zhang <i>et al.</i> (2017)	2017	<i>Escherichia coli</i>	72	91.67%	Northeast	4
Zhang, (2016)	2016	BVDV	50	48.00%	Northeast	4
Zhang, (2016)	2016	BCV	125	26.40%	Northeast	2
Zhang, (2016)	2016	BRV	125	46.40%	Northeast	4
Zhao, (2018)	2018	BCV	247	5.67%	Central	3
Zhao, (2018)	2018	BRV	247	13.77%	Central	4
Zhao, (2018)	2018	<i>Cryptosporidium</i>	247	29.15%	Central	3

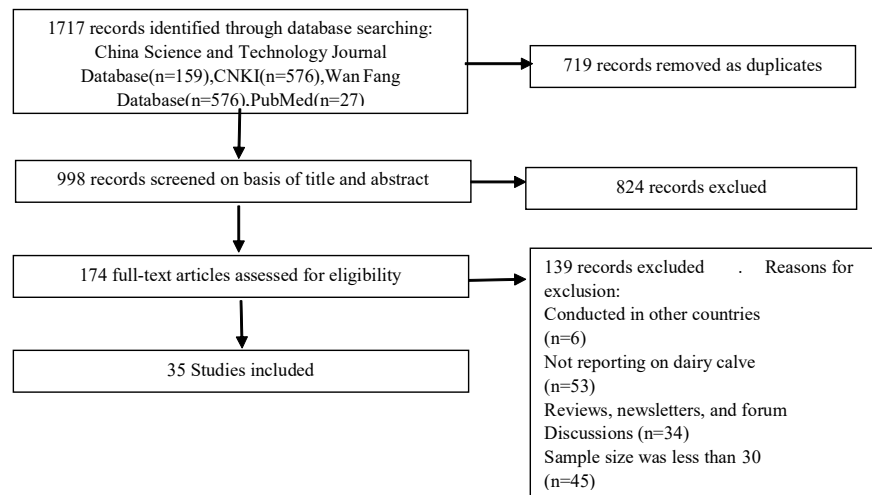
The table shows publication years, pathogen causing diarrhea in calves, number of samples, positive rate, research areas and paper quality scores. The score in each followed item was determined as 1, including target, detection methods used, sampling method, subgroup classification in the study.

### Diarrhea prevalence of dairy calves during different periods in China

All the study date was divided into two periods: early (1992-2009) and recent (2011-2018) for subgroup analysis. During the early period, a few literature on dairy calves' diarrhea was observed, but there was a higher prevalence of 45.4% (95% CI 0.33-0.58). However, in the recent period, the

diarrhea prevalence significantly decreased to 17.3% (95% CI 0.15-0.19).

In this systematic review, a meta-analysis validated that diarrhea in dairy calves was widely distributed throughout China and the average diarrhea prevalence was 27.2% from the year 2003 to 2018. Nationwide, bacteria resulted in the highest diarrhea prevalence approximate 39.2%, among which the Northeast, Northwest, East China and North China



Flow chart 1: Flow diagram of literature search and selection.

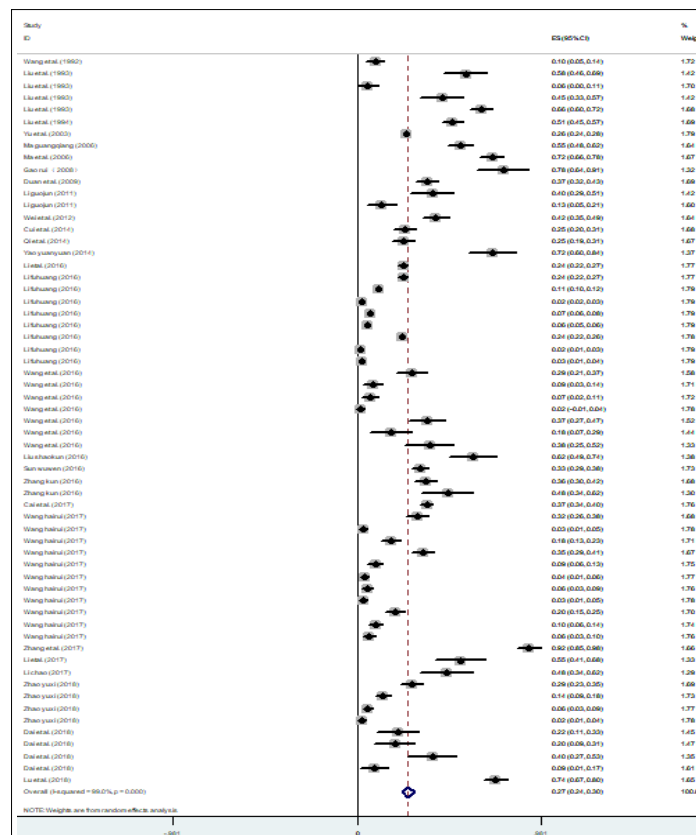


Fig 1: Funnel plot with pseudo 95% confidence interval. Funnel plot shows the incidence of diarrhea in calves, indicating that there is significant heterogeneity in the literature.



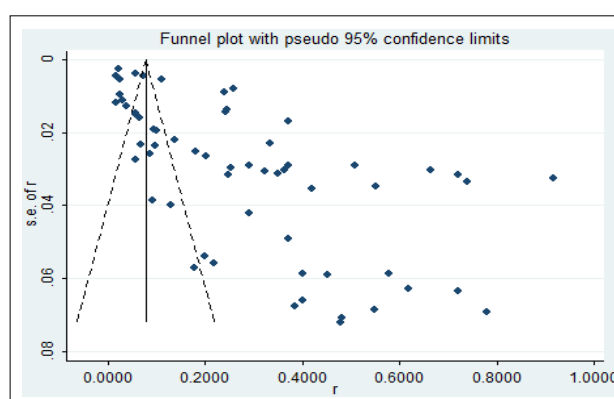
were in the forefront, with 36.2%, 32.5%, 36.5% and 30.2%, respectively. However, the prevalence of diarrhea caused by bacteria was only 6.6% in Central China, which was far lower than the national average. It might due to the central part of China was not the primary producing area of China dairy farming, thus the probability of infection was lower than other areas. Mean while, the present study showed that the main pathogen result in calves' diarrhea was *Escherichia coli* and its prevalence rate was 44.1%. Sun, (2016) isolated 140 strains of *Escherichia coli* from 420 fecal samples of diarrhea calve from six provinces and cities in northern analyzed its pathogenesis and distribution of the O serotypes. The results indicated that all the isolated strains contained 15 serotypes, where O14, O15, O101, O78 and O36 were dominant serotypes. Pathogenesis island (HIP) was found positive in 59 strains and the positive rate was 42.14% (59/140). Zhang *et al.*, (2017), collected 72 pathological materials from different organs (intestines, lungs, urachus, real stomach, *et al*) of dead calves and identified 63 *Escherichia coli* strains. The results showed that the virulence factors were involved in 46 strains of *Escherichia coli*, in which 18 strains carrying CS31A gene accounted for 39.13%, indicating the CS31A gene was the dominant gene-A total of 35 strains in enterotoxigenic *Escherichia coli* (ETEC) were identified through typing the *Escherichia coli* by virulence factors, accounted for 76.09%, demonstrating that ETEC was the principle pathogenic type resulting in calves' diarrhea. Li *et al.*, (2018) isolated 29 strains of *Escherichia coli* from fecal samples in 53 diarrhea calves in a cattle farm in Xinjiang province and observed that the dominant serotype was O78. Among 29 strains of *Escherichia coli*, 7 strains presented high virulence, accounting for 24.14%. The isolated strain was sensitive to azithromycin and the sensitive rate was 89.66%.

Meta-analysis results indicated that the diarrhea prevalence caused by the virus in Northwest and Northeast China was 26.2% and 22.2%, respectively. However, that diarrhea prevalence was remarkably decreased in East China, North China and central China, with decreased by 13%, 10% and 8.4%, respectively. The present study indicated that bovine rotavirus (BRV), bovine viral diarrhea virus (BVDV) and bovine coronavirus (BCV) were the dominant pathogens in viral diarrhea of calves and the corresponding prevalence was 32.7%, 22.2% and 3%. This showed that rotavirus was the main pathogen that caused diarrhea in calves.

In Northwest China, (Duan *et al.*, 2009) detected rotavirus using the ELISA method in 274 fecal samples of diarrhea calves from 7 large cattle farms in Xinjiang and the average positive rate was 37.2%. Another literature reported that 172 calf diarrhea samples were collected from Xinjiang for rotavirus detection and the positive rate of the samples was as high as 72% (Lu *et al.*, 2018). In Northeast China, Previous literature reported that the positive rate of rotavirus in diarrhea fecal samples was 57.8%, while no coronavirus

was found (Wang *et al.*, 2016). A study in Henan Province in Central China indicated that the positive rate of rotavirus and coronavirus in fecal samples of diarrhea calf was 12.24% and 4.76%, respectively (Zhao 2018). Yu, (2003) detected BVDV in serum samples of newborn calves from some cattle farms in Nanjing in East China and the positive rate was 25.96%. These studies showed that rotavirus was the most dominated pathogen in viral diarrhea calves and a general infection of rotavirus was observed in dairy-producing areas in the northwest and northeast, while the diarrhea caused by coronavirus was the lowest. From the perspective of regional differences, the risk and probability of rotavirus infection were higher in the Northwest than those in East China, North China and central China. The probable reason was that the Northwest and the Northeast were the main production areas of dairy cows in China and the number of cows was larger, which posed a threat to dairy farming in this region. From 2009 to 2018, the diarrhea rate of calves caused by rotavirus did not decrease in the main production areas of dairy cows feeding, reflecting that bovine rotavirus was not effectively controlled and there was a widespread infection by bovine rotavirus. In the long term, it is necessary to make a comprehensive intervention strategy to continuously and epidemiology monitor rotavirus infection in dairy calves.

The present results showed that the highest prevalence of diarrhea caused by the parasite was 24% in Northwest China, followed by 17.8% in Central China and 10% in North China. There were only two reports on both Northeast China and East China in the existing literature, in which the prevalence rates in Northeast China was 17.8% and 1.7%, respectively and the prevalence rates of the two cases in East China were 37% and 1.7%, respectively, quite different from each other. Therefore, more in-depth and comprehensive investigations are recommended in these



**Fig 2:** Forest plot of prevalence of dairy calves' diarrhea in China. The study names included in the analysis are shown in Table 1 with their corresponding effect size and 95% confidence interval (CI). The overall effect is shown at the bottom, represented by shaded diamond. The vertical dotted line represents a risk ratio (RR) of 1, indicating no significant difference in literatures.

two areas to verify the diarrhea prevalence in dairy calves caused by parasites and to emphasize interventions to control parasite infection. Our study further found that *Cryptosporidium* was the main pathogen causing calves' diarrhea in parasites infection and that prevalence was 14.1%. *Cryptosporidium* can be transmitted by food, water and direct or indirect contact. Previous studies showed that *Cryptosporidium* could be mixed with rotavirus and caused diarrhea in calves (Wang *et al.*, 2016). Dai *et al.*, (2018) found that *Cryptosporidium* infection might be related to polluted water sources in dairy farms. The oocysts of *Cryptosporidium* are mostly discharged at night, thus they can be cleaned and disinfected in the early morning. In addition, the chlorine contained in disinfectant had a good killing effect on *Cryptosporidium* in drinking water and the killing rate could be greater than 99% (Liu *et al.*, 2013).

There were also some limitations in our analysis. Firstly, some relevant research were obtained through systematic review, but these searches might not cover all studies. Secondly, the data used in this analysis considered only the publication year, geographical location or testing methods, other than potential risk factors, such as the type of cattle including free range or intensive breeding. Finally, the present study did not consider the effects of different strains and virus types on calves' diarrhea, which would be further analyzed in the future research.

## CONCLUSION

In summary, diarrhea is an important disease in newborn dairy calves. The prevalence of diarrhea is different in different areas and different pathogens. In the future, more extensive surveys should be carried out and based on this to take corresponding measures to decrease the incidence and prevalence of dairy calves.

## ACKNOWLEDGEMENT

This project was supported by National Natural Science Foundation of China (Grant No. 31902186; Grant No.32072758), Scientific Research Starting Foundation for Returned Overseas Chinese Scholars (Grant No.ZRCLG201903), The Natural Science Foundation of Heilongjiang Province of China (Grant No. LH2021C069), Major Science and Technology Project of Heilongjiang Province (Grant No. 2021ZX12B03).

## Conflict of interest

We certify that there is no conflict of interest with any financial organization regarding the material discussed in the manuscript.

## REFERENCES

- Cai, M., Guo, Y.Q., Pan, B.L., Li, N., Wang, X.L., Tang, C.X. *et al.* (2017). Longitudinal monitoring of *Cryptosporidium* species in pre-weaned dairy calves on five farms in Shanghai, China. *Vet Parasitol.* 241: 14-19.
- Chang, L.Y., Liu, Z.Y., Qing, J.H., Zhao, Y.L. (2021). Epidemiological investigation on viral diarrhea of dairy calves in Tangshan city, Hebei Province. *China Animal Husbandry and Veterinary Medicine.* 48(12): 4537-4544.
- Chen, Y.B., Zang, M.Y., Li, L., Wu, E.B., Ma, Y.B. (2020). Epidemiological investigation on viral diarrhea of pregnant aborted cows and diarrhea calves in Hebei Province. *Chinese Journal of Veterinary Medicine.* 48(11): 4213-4219.
- Cheng, B.W. (2019). Investigation and analysis of cryptosporidiosis in dairy cows with diarrhea in Jiaxian County, Henan Province. *Chin Dairy.* 208: 85-86.
- Cui, X. (2019). Epidemiological Survey of Round and Coronavirus in Some Large-scale Dairy Farms in Southern Xinjiang [master's thesis]. TRM, CHN: Tarim University.
- Cui, Z.H., Wang, R.J., Huang, J.Y., Wang, H.Y., Zhao, J.F., Luo, N.N. (2014). Cryptosporidiosis caused by *Cryptosporidium parvum* subtype 1dA15G1 at a dairy farm in Northwestern China. *Parasit Vectors.* 7: 529. DOI:10.1186/s13071-014-0529-z.
- Dai, S.H., Li, C., Li, Z.Q., Lu, J.Y., Wang, T.Y., Dong, Q. (2018). Etiological investigation of 55 cases of diarrhea in calves of two dairy farms. *Prog. Vet. Med.* 39: 134-136.
- Duan, X.H., Wang, Z.C. (2009). Investigation on the prevalence of bovine rotavirus diarrhea in Xinjiang calves. *Chin Dairy Cattle.* 11: 41-42.
- Gao, R. (2008). Epidemiologic Investigation and Primary Immunologic Test of Cattle *Escherichia coli* Diarrhea in Shaanxi Province [master's thesis]. SN, CHN: Northwest A and F University.
- Jia, D., Dan, J.M., Sun, Y., Luo, J.Y., Zhu, Z.Q., Zhang, X.P. *et al.* (2019). Prevalence and molecular characteristics of cryptosporidium infection in pre-weaned dairy calves in Sichuan Province. *Chin J. Parasitol Parasit Dis.* 37: 422-427.
- Jumabieke, X., Ma, X.Y., Wang, W. *et al.* (2021). Analysis of infectious calf diarrhea in large-scale cattle farms in Northern Xinjiang. *Journal of Herbivorous Livestock.* 45-50.
- Kang, Q., Chen, Y.B., Guan, Y.F., Li, L., Qin, J.H., Zhao, Y.L. (2019). Isolation and identification of *Cryptosporidium andersoni* in calves from dairy farm in Hebei province. *Chin J. Vet. Sci.* 39: 1325-1329.
- Li, C. (2017). Isolation and Identification and Study on Part of the Biological Characters of Vancomycin-resistant *Enterococcus faecalis* from Calve Diarrhea [Master's thesis]. SHZU, CHN: Shihezi University.
- Li, F.H. (2016). The Investigation of Major Pathogens Causing Calf Diarrhea and their Control in Beijing [doctor's thesis]. BJ, CHN: China Agriculture University.
- Li, G.J. (2011). The Study of Control and Treatment Calf Diarrhea by Montmorillonite [Master's thesis]. QHD, CHN: Hebei Agriculture University.
- Li, H., Zhang, H.L., Qi, Y.Y. (2018). Pathogenic analysis of calf diarrhea in a large-scale cattle farm in Shihezi. *HL Anim. Sci. Vet. Med.* 23: 102-104+269.
- Li, J.Q., Luo, N.N., Wang, C.R., Qi, M., Cao, J.K., Cui, Z.H. (2016). Occurrence, molecular characterization and predominant genotypes of *Enterocytozoon bieneusi* in dairy cattle in Henan and Ningxia, China. *Parasit Vectors.* 9: 142. doi: 10.1186/s13071-016-1425-5.
- Liu, S.Y., Zhang, G.Q., Pang, Q.F. (1993). Experimental report on the prevention and treatment of calf diarrhea with 372 Zhixieling. *SH J. Anim. Husb. Vet. Med.* 2: 11-12.
- Liu, L.N., Zhang, X., Cui, C.W., Sun, X.B. (2013). Experimental study on cryptosporidium inactivation in drinking water by chlorine-based disinfectants. *J. Harbin Univ Commer (Nature Sci).* 29: 412-415.

- Liu, S.K. (2016). Identification of calf diarrhea in some areas of Beijing and Tianjin and drug resistance of *E. coli* isolated [master's thesis]. CC, CHN: Jilin Agriculture University.
- Lu, Y.D., Liu, X.X., Chen, C.F. (2018). Investigation of bovine rotavirus viral causing calf diarrhea in some areas of Xinjiang. *XJ Farm Res. Sci. Tech.* 41: 25-27.
- Ma, G.Q. (2006). Study on rapid diagnosis of bovine bacterial diarrhea [master's thesis]. SD, CHN: Agriculture University.
- Ma, G.Q., Zhang, W.J., Luan, J.J., Lin, S.Q., Yang, S.H., Liu, W.Q. *et al.* (2006). Direct detection of the enterotoxigenic *Escherichia coli* in bovine feces by multiplex PCR. *Chin J. Zoonoses.* 22: 153-156.
- Meng, Q.S., Ji, Y., Zhang, X.C., Zhu, N.N., Wu, H. (2019). Seroepidemiological survey on bovine viral diarrhea virus infection in some areas of China in 2018. *Chin Dairy Cattle* 2019. 2: 22-24.
- Ma, X.Y. (2021). Analysis of infectious diarrhea of calves on large-scale cattle farms in Northern Xinjiang. *China Animal Husbandry and Veterinary Medicine*.
- Qi, M.Z., Fang, Y.Q., Wang, X.T., Zhang, L.X., Wang, R.J., Du, S.Z. (2015). Molecular characterization of *Cryptosporidium* spp. in pre-weaned calves in Shaanxi Province, North-Western China. *J. Med. Microbiol.* 64: 111-116.
- Rucker, G., Schwarzer, G., Carpenter, J.R., Schumacher, M. (2008). Undue reliance on I2 in assessing heterogeneity may mislead. *BMC Med. Res. Methodol.* 8: 79.
- Sun, P.J. (2003). Calf diarrhea: The killer of newborn cattle. *Chin Anim. Husb. Vet. Med.* 4: 44.
- Sun, W.W. (2016). Studies on the HPI molecular structures and bacterial ghosts of *E. coli* strains causing diarrhea in calf from farms in northern China [doctor's thesis]. CC, CHN: Jinlin Agriculture University. 2016.
- Wang, H.R. (2017). The investigation of major pathogens of the calf diarrhea and the analysis of biological characteristics of *E. coli* in 13 provinces, China [master's thesis]. LZ, CHN: Chinese Academy of Agriculture Science. 2017.
- Wang, S.J., Lu, L.Y., Zhang, G.J., Yang, L.H., Yang, R.H. (1992). Epidemic and control of bovine viral diarrhea viral disease in calves. *Chin J. Prev. Vet. Med.* 65: 20-21.
- Wang, S.Y., Huang, M.Z., Wang, H., Cui, D.A., Qi, Z.M., Liu, Y.M. (2016). Pathogen investigation and logistic regression with clinic symptom of calf diarrhea disease. *J. Tradit. Chin Vet. Med.* 35: 7-10.
- Wang, W.J., Cheng, C., Zhang, K., Sun, X.P., Xu, L.H. (2019). Investigation of various pathogens causing calf diarrhea in Ningxia Hui Autonomous Region. *Anim. Husb. Vet. Med.* 51: 107-109.
- Wang, W.J., Shi, H.Z., Lan, Y.L., Xu, Z.X. (2019). Establishment and preliminary application of dual PCR for detection of bovine norovirus and coronavirus. *Animal Science and Veterinary Medicine.* 40(10): 6-9.
- Wang, X. (2021). Investigation on the prevalence of pathogens in feces of Suckling calves with diarrhea. *Chinese Cows*.
- Wang, Y.L., Guo, Z.J., Yue, H., Tang, C. (2019). Detection and Evolutionary analysis of bovine noroviruses in diarrheic fecals of dairy calves in some areas. *Xu Mu Shou Yi Xue Bao.* 50: 1048-1055.
- Wei, S.C., Gong, Z.D., Che, T.J., Ayimu, G., Tian, F.L. (2013). Genotyping of calves rotavirus in China by reverse transcription polymerase chain reaction. *J. Virol. Methods.* 189: 36-40.
- Yan, T.B., Li, Z.Y., Lv, H.M., Zhang, D.F., Peng, Z. (2020). Investigation on main pathogen of calf diarrhea in Henan Province. *China Cattle Science.* 2(3)OAJBS.ID.000177. DOI: 10.38125/OAJBS.000177.
- Yao, Y.Y. (2014). A study on the isolation and identification of *E. coli* from calf diarrhea and antimicrobial effect of Mongolian medicine on them [Master's thesis]. HET, CHN: Inner Mongolia Agriculture University. 2014.
- Yao, Z.L., Fu, H.Q., Cui, P.F., Zong, J.L. (2019). Molecular epidemiology of bovine viral diarrhea virus and identification of a BVDV-2 isolate in regional area of Jiangsu and Zhejiang provinces. *J. YZ Univ (Agric Life Sci).* 40: 40-46+102.
- Yao, Y.Y., Wang, C.J., Ao, R.G.L. (2014). Effect of traditional Mongolian medicine compound Bab-7 on *E. coli* causing diarrhea in calves. *Contemporary Animal Science.* 72-74.
- Yu, Y.R., Xu, B.K., Qin, X.Y., Wu, H.H. (2003). Serological investigation of bovine viral diarrhea viral disease in newborn calves in Nanjing. *Chin J. Vet Sci Tech.* 33: 46-48.
- Zhang, K. (2016). Investigation of calves viral diarrhea related pathogen of large-scale farm in northern XinJiang region [Master's thesis]. SHZU, CHN: Shihezi University. 2016.
- Zhang, K.K. (2019). Epidemiological survey of *Cryptosporidium parvum* in neonatal calves in parts of Xinjiang [master's thesis]. TRM, CHN: Tarim University.
- Zhang, Z., Song, M.Y., Zhi, Y., Ji, Y.N., Zhao, B.B., Xia, M. *et al.* (2017). Investigation and analysis of the virulence factors of pathogenic *Escherichia coli* from some cattle ranches in Heilongjiang Province. *HL Anim. Sci. Vet. Med.* 3: 160-162+166.
- Zhao, Y.X. (2018). Investigation on main pathogens of calf diarrhea in Henan Province and verification of microfluidic chips for calf diarrhea [Master's thesis]. ZZ, CHN: Henan Agriculture University.
- Zhi, H.D., Gao, Y., Liu, C.M., Fu, Z.Y. (2015). Research progress in etiology of infectious calf diarrhea. *HL Anim. Sci. Vet. Med.* 23: 73-76.